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Study of Micrometeroid Orbital Debris

by

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and

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INTRODUCTION

The measurement of high velocity impact dynamics in ground based ballistic gun facilities provides a useful and inexpensive methodology for simulating space meteroid impact phenomena. Major thrusts are underway to measure the effects of impact damage at ballistic velocities on space related structural shells, in order to better understand the long term safety characteristics of materials in space, as well as to evaluate the materials currently available for platforms such as the Space Station.

The results of the high impact damages can be measured in a number of different ways in order to evaluate the effects of high velocity impact on structures. The hyperbolic velocity of micrometeroids occur in the velocity range 15 - 20 km/sec, randomly distributed in all directions. On the other hand, space debris occupy circular orbits in the range 7 - 10 km/sec. Relative velocities of these particles with a space platform would then be in the range 8 - 20 km/sec for meteroids and 3 - 12 km/sec for space debris.

Damage assesment studies have shown that impacts above the ballistic limit provide a number of measurable parameters, such as impact flash, penetration depth, spall/fracturing and shear cone. Impacts below the ballistic limit provide information from buckling, mushrooming of the impactor, and embedding. Resulting differences in the target also occur depending upon differences in geometry of the projectile, and relative values of hardness and density between the projectile and the target. Experimental data obtained during the impact experiments are already recorded and consist of kinetic energy data and flash x-ray images. These items are already deposited with other appropriate information stored at MSFC. The mechanical parameters obtained after the impact experiments are the major goal of this report.

Projectile velocities of 3 to 7 km/sec are achievable in the light gas gun at MSFC for particle diameters in the range between 3 to 8 mm. The types of damage observed with a variety of space station bumper and shield materials includes the following:

- Craters A divot located on the front panel causing a dimple on the back side.
- Dimples An outward indentation in the panel on the backside.
- Detached spall Material missing from the backside of the panel.
- Attached spall Material deposited on the backside of the panel.
- Fine spray Small craters that do not create dimples.
- Petals Material that is bent toward the projectile exit.
- Damage diameter The area affected by the projectile.
- Number of holes Total number of pnetrtion holes.
- Deformation A measurement of the deflection of the plate after impact.
- Wagon wheel A fine spray that appears to look like a starburst.

RESULTS - see attached sheets

Several craters/dimples, largest .185x.074 deep, dam area 7x7.5 Approx. 20 craters/dimples, dam area 7.25x7.,2 detached spalls Many craters, wagon wheel, dam area 10.5"dia, detached spalls Fine spray, many craters/dimples, lg crater..16" dia x .089 deep 8 lg. craters/dimples, fine spray, dam area 5.75x7, detached spall Fine spray, lg. crater .17"x.22"x.06" deep, damage area 6"x7.5" 2nd hole .22x0.17", 3rd hole has 4 petals, pin holes, fine spray Detached spalls, wagon wheel, 9 dimples, dam area 8.5 x 8.0" Many craters/dimples, largest .25x.13 deep, dam area 7.5 dia holes, 5 detached spalls, wagon wheel, dam area 12" x10.5" 8 lg. craters, several sm. craters, dam area1.75"x2.4", dimples 5 measurable holes 0.08,0.09,.16x0.06,.06", detached spalls 3 detached spalls, 6 dimples, dam area 9.5" x 11", fine spray Approx. 8 craters with dimples, Damage area: 0.75" x 1.25" Approx. 14 craters/dimples, dam area 6.5x6.0, fine spray Material peeled back around hole, craters, no dimples ~ 8 craters, small crack, damage area 1.5" x 2.0" Numerous holes, wagon wheel, detached spalls 11 holes, detached spalls, dam area 10"x12" Numerous craters, Dam. Area 1.75" x 2.0" 2 craters, largest 0.07"x0.13"x0.02" deep craters/dimples, deepest crater 0.03 Material peeled back around hole 6 craters, 1 hole with 3 petals I detached spall on backside Fine spray, no dimples Damage Description 6 craters, 4 dimples Missing 3 holes 1.23,1.09,0.97,0.44,1.19,1.32,0.8" 0.58", 0.65", 0.22" Petal Length of Crack Petals 0.118",0.107"0.122 0.19",0.125",0.04" _ ~ ~ ~ Max:1.18 x 0.84" 0.406" & 0.096" Max:0.17x0.08" Max:0.14x0.16" 0.418" x 0.513" Max 1.4" x 1.6" Hole Diameter 0.52" x 0.46" 0.54" x 0.64" 0.45" x 0.42" 0.55" x 0.57" 2.28"x1.09" 0.06" Dia. 0.59" dia. 0.55" Dia. 0.44" dia. Pin Hole 0.50" dia 0.336" 0.332" 0.458" 0.432" 0.125" 0.388" 0.69" Pen. Ę. Yes Yes Yes چ إ Xes No Yes ž Yes ž S_N ž ٩ οN Yes Yes ŝ Yes Yes Yes Yes ŝ Yes Yes å ŝ ž Thickness 0.040" 0.080 0.125" 0.125" 0.050" 0.020" 0.125" 0.020" 0.125" 0.125" 0.040" 0.125" 0.040" 0.040" 0.125" 0.020" 0.020" 0.125" 0.020" 0.125" 0.125" 0.125" 0.125" 0.020" 0.125" 0.080" 0.125" 0.020" 0.020" 0.080 0.125" 0.063 Matrix #PR-1730 Matrix #PER-2486 Matrix #PER-2505 Matrix #PER-2908 Matrix #D1813 Matrix #D1813 2219-T87 AI 2219-T87 Al 2219-T87 AI 2219-T87 AI 2219-T87 AI 2219-T87 Al 2219-T87 AI 6061-T6 AI 6061-T6 Al 2219-T87 AI 6061-T6 AI 6061-T6 Al 6061-T6 Al 6061-T6 AI 6061-T6 Al 6061-T6 Al 2024 AI 2024 Al 2024 AI Material 2024 AI 2024 AI 2024 AI 2024 A1 2024 AI 2024 AI Witness #2 Witness #1 Description Witness #1 Witness #1 Witness #1 Shield #1 Shield #1 Shield #1 Shield #1 Shield #1 Shield #1 Witness Bumper Witness Witness Bumper Bumper Bumper Bumper Bumper Bumper Bumper Bumper Witness Witness Bumper Shield Wall Wall Wall Wall Wall Wall Wall Wall Wall ₩al Wall Wall Wall Wall Wall Wall 45 deg target angle 45 deg target angle 45 deg target angle 0 deg. target angle 0 deg target angle 0.187" Al-1100 0.187" Al-1100 0.187" Al-1100 0.250" Al-1100 0.250" AI-1100 0.250" AI-1100 0.250" AI-1100 0.250" AI-1100 0.187" Al-1100 0.187" Al-1100 0.187" Al-1100 0.187" Al-1100 0.250" Al-1100 0.250" Al-1100 0.250" Al-1100 0.187" Al-1100 0.187" Al-1100 0.25" AI-1100 0.25" AI-1100 2nd Projectile Aluminum Projectile 1345 1346 1336 Shot 1316 1324 1326 1328 1329 1331 1332 1339 1341 1343 1320 1338 340 1342 1327 1321

Shot	2nd Projectile	Description	Material	Thickness	Pen	Hole Diameter	Petal I	Length of Crack Petals	Damage Description
1348	0.250" AI-1100	Wall	2219-T87 Al	0.125"	Yes	П			1 crater w/ dimple, fine spray
1349	0.250" Al-1100	Shield #1	6061-T6 Al	0.050"	Yes	0.51" dia.			
	0 deg. target angle	Wall	2219-T87 AI	0.125"	Yes		3 (0	0.80",0.77",0.47"	Numerous small holes, lg. detached spail 1.8x1.63", fine spray
		Witness #1	2024 AI	0.020"	Yes	Overall 1.93x1.15			Small crack to the left of holes
		Witness #2	2024 Al	0.020"	οN				13 large craters
1350	0.250" Al-1100	Shield #1	6061-T6 Al	0.050"	Yes	0.50" dia			
	0 deg. target angle	Stuffing	MLI		Yes	See photo			
		Wall	2219-T87 Al	0.125"	Yes	Max:.32"x0.22"			
1353	0.375" Al-1100	Shield #1	6061-T6 Al	0.050"	Yes	0.59" dia.			
		Shield #2	6061-T6 Al	0.050"	Yes	3.4" x 4.6"			Damage area radiates the whole pattern, wagon wheel
		Stuffing	MLI	20 layers		See photo			
		Wall	2219-T87 AI	0.125"	No				No perforation, damage area ~5"
1357	0.375" Al-1100	Shield #1	6061-T6 Al	0.063"	Yes	0.64" & 0.37"			
	0 deg. target angle	Stuffing		2 layers	Yes				
		Wall	2219-T87 Al	0.125"	Yes	Cracks/Pin holes	\exists		2 cracks 6.875" & 1.03", damage area ~ 6.875" x 3.5"
1358	0.375" AI-1100	Shield #1	6061-T6 AI	0.063"	Yes	0.64"	7		Secondary hole 0.38"
	0 deg. target angle	Stuffing		2 layers		See photo			
		Wall	2219-T87 Al	0.125"	No				Plate deflected ~ 0.60" damage area 4" dia
1359	0.375" AI-1100	Shield #1	6061-T6 Al	0.063"	Yes	0.64" dia.			
		Wall	2219-T87 Al	0.125"	No				~ 0.5" deflection of plate, damage area 5.5" x 5.0"
1360	0.250" AI-1100	Stuffing	MLI	20 layer	Yes	See photo			
	0 deg. target angle	Shield #1	6061-T6 Al	0.050"	Yes	0.52" dia.			
		Wali	2219-T87 Al	0.125"	Yes	0.14x0.15"			2nd hole .17x.07, 3rd .12x.05, 4th .07" d,dam area 8.5x7.875"
		Witness #1	2024 AI	0.020"	No				9 craters with dimples, dam area 2.875" x 2.0"
1362	0.375" AI-1100	Stuffing	MLI	20 layer	Yes	See photo			
	0 deg. target angle	Shield #1	6061-T6 AI	0.050"	Yes	.070" dia.			
		Wall	2219-T87 Al	0.125"	Yes	3.0" x 2.2"			Wagon wheel, detached material on rear, dam area 8.5" x 11"
		Witness #1	2024 AI	0.020"	Yes		6		Damage area 4.375" x 4.75"
		Witness #2	2024 AI	0.020"	Yes		6		Damage area 4.25" x 3.75"
		Witness #3	2024 AI	0.020"	Yes		7		Damage area 2.75" x 3.00"
1363	0.375" Al-1100	Shield #1	6061-T6 Al	0.063"	Yes	0.64"			2nd hole 0.44 x 0.36", 3rd 0.22" x 0.17"
	0 deg. target angle	Honeycomb			Yes	See photo			
1364	0.375" Al-1100	Shield #1	6061-T6 AI	0.063"	Yes	0.64" dia.			
	0 deg. target angle	Shield #2	Lanxide Comp.	0.123"	Yes	2.06 x 1.95"			Wagon wheel
		Wall	2219-T87 AI	0.125"	Yes		3	4.3",3.92",2.17"	Damage area 5.25 x 6.5"
		Witness #1	2024 Al	0.020"	ν̈́				~ 6 craters w/ dimples, damage area 4.5" x 2.25"
1366	0.375" AI-1100	Shield #1	6061-T6 Al	0.063"	Yes	0.64" dia.			Secondary hole 0.39" x 0.34"
	0 deg. target angle	Shield #2	Lanxide Comp.	0.061"	Yes	2.34" x 2.40"			Wagon wheel
		Wall	2219-T87 AI	0.125"	Yes		9	7	Damage area 4.75" x 5.0"
		Witness #1	2024 A1	0.020"	Yes		4	1.66,1.96,1.02,1.52,1.50"	Damage area 4.5"
		Witness #2	2024 A1	0.020"	Yes	1.65" x 0.56"	5		Elongated hole, damage area 2.0" x 2.0"
1367	0.375" Al-1100	Shield #1	6061-T6 AI	0.063"	Yes	0.63" dia.			
	0 deg. target angle	Shield #2	Lanxide Comp.	0.061"	Yes	1.64" dia.			Material deposited on front and rear of panel
		Shield #3	Lanxide Comp.	0.061"	Yes	~2.0" dia.	7	2.63,2.43,.62,1.24,1.85,2.14,2.1. Plate broke in 3 pcs.	Plate broke in 3 pcs.
		Wall	2219-T87 Al	0.125"	ž				Plate deflected ~ 0.57", damage area 4.0" dia., fine spray

0.375 Al-1100 Sineld #1 6661 TrS Al 0.067 TrS Vis. 1 0.645 Lil.85 0.4cg target maple Sineld #2 Lannich Comp 0.032 TrS Yes 6.67 TrS 6.05 Lil.185 0.375 Al 1100 Sineld #3 Lannich Comp 0.0127 Yes 0.467 Dis 6.95.75.60.65.07.11.05 0.4cg target maple Sineld #3 Lannich Comp 0.0127 Yes 0.467 Dis 6.77.1.43.13.11.31.74.156 0.4cg target maple Sineld #3 0.032 Yes 0.467 Dis 6.721.24.13.31.13.174.156 0.4cg target maple Sineld #3 0.032 Yes 0.467 Dis 6.721.24.13.31.13.174.166 0.375 Al-1100 Sineld #3 0.027 Yes 0.047 X.0.22 7.210.175.206.195.1.25.197.2 0.4cg target maple Sineld #3 0.032 Yes Ves 0.467 X.0.42 7.210.175.206.195.1.23.197.2 0.4cg target maple Sineld #3 0.045 Yes 0.047 X.0.44 0.017 X.0.44 0.047 X.0.42 0.4cg target maple Sineld #3 0.066-176.Al 0.057 Yes 0.047 X.0.44 0.047 X.0.44 0.4cg target maple Sineld #3 <th>Shot</th> <th>2nd Projectile</th> <th>Description</th> <th>Material</th> <th>Thickness</th> <th>Pen.</th> <th>Hole Diameter</th> <th>Petal</th> <th>Petal Length of Crack Petals</th> <th>Damage Description</th>	Shot	2nd Projectile	Description	Material	Thickness	Pen.	Hole Diameter	Petal	Petal Length of Crack Petals	Damage Description
O deg maget maple Shield #2 Lamotide Comp. 0.031 Yes 5.5 x 4.07 4 0.77.04.4.2.1.85* 0.355 x 4.1100 Shield #3 Lamotide Comp. 0.031 Yes 5.5 x 4.07 4 0.77.04.4.25.1.87* 0.355 x 4.1100 Shield #3 2.215-1.87 0.002 Yes 0.46°Dia. 6 72.1.34.1.31.5.1.74.1.66 0.355 x 4.1100 Shield #3 0.002 Yes 0.46°Dia. 6 72.1.24.1.33.1.5.1.74.1.66 0.355 x 4.1100 Shield #3 0.002 Yes 0.47°x 0.42° 7 2.19.1.75.2.06.1.95.1.22.1.97.2. 0.45 mind #4 0.606-176 A1 0.002 Yes 0.47°x 0.42° 7 2.19.1.75.2.06.1.95.1.22.1.97.2. 0.45 myet maple Shield #1 6061-176 A1 0.002 Yes 1.47°x 0.42° 7 2.19.1.75.2.06.1.95.1.22.1.97.2. 0.45 myet maple Shield #1 6061-176 A1 0.002 Yes 1.47°x 0.44° 0.19.1.7.2.2.0.6.1.97.2. 0.47°x 0.44°	1368	0.375" Al-1100	Shield #1	6061-T6 AI	0.063"	Yes				
Shield #3 Lawide Comp 0.015" Yes 55" x 4.0" 4 0.37, 0.44, 2.5, 1.48" 0.375 x 1 1100 Shield #1 2.219-T87 Al 0.020" Yes 0.46" Dia. 6 55.3.1.56.055.071,1.05 0.46g target angle Shield #1 0.020" Yes 0.46" Dia 6 72.1.24,1.31.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.		0 deg. target angle	Shield #2	Lanxide Comp.	0.031"	Yes	1.80" dia.		0.96,1.21,1.85"	Damage area 4" dia.
Well 219-T87 AI 0.050 Yes Ode/Dis 0.457-AI 1100 Shield 47 0.050 Yes 6 96.37,56.065.071,105 0.45g-mager angle Shield 47 0.032 Yes 6 721,241,331,51,741,66 0.45g-mager angle Shield 47 0.032 Yes See photo 6 721,241,331,51,741,66 0.375-AI-1100 Shield 47 0.032 Yes 3.60-10,135,017 7 219,175,2.06,195,1.52,197,2 0.475-AI-1100 Shield 47 0.032 Yes 1.40-17,3.04 7 219,175,2.06,195,1.22,197,2 0.45g-mager angle Shield 47 0.040 Yes 1.40-17,0.04 7 219,175,2.06,195,1.22,197,2 0.45g-mager angle Binaker MAIL Blanker 2.01-17,0.04 Yes 1.40-17,0.04 0.45g-mager angle Shield 47 0.060-176,41 0.047,0.04 Yes 1.40-17,0.04 0.45g-mager angle Shield 47 0.061-176,41 0.037 Yes 1.40-17,0.04 0.45g-mager angle Shield 47 0.061-176,41 0.037 Yes 1.40-17,0.04 0.45g-mager an			Shield #3	Lanxide Comp.	0.031"	Yes	5.5" x 4.0"		0.37, 0.44, 2.5, 1.48"	
0.375 A.1100 Shield #1 0.0027 Yes 0.45° Dia. 6 73.7.50.05.05.07.105 0.402 unger angle Shield #2 0.0027 Yes See photo? 7.2.124.1.33.1.3.1.74.166 0.375 A.1.100 Shield #2 0.0027 Yes 3.6e photo? 7.2.124.1.33.1.3.1.74.166 0.375 A.1.100 Shield #1 0.027 Yes 3.6e photo? 7.2.124.1.33.1.3.1.74.166 0.375 A.1.100 Shield #1 0.020 Yes 1.4e photo? 7.2.124.1.33.1.3.1.3.1.74.166 0.375 A.1.100 Shield #1 0.605.16 A.1 0.020 Yes 1.4e photo? 7.2.124.1.33.1.3.1.3.1.3.1.74.166 0.375 A.1.100 Shield #1 0.605.16 A.1 0.020 Yes 1.4e photo? 0.127.1.44.1.3.1.3.1.3.1.3.1.3.1.3.1.7.1.166 0.45 urget maps Shield #1 0.605.16 A.1 0.125 Yes 1.4e photo? 0.27.1.24.1.3.3.1.3.1.3.1.3.1.3.1.3.1.3.1.3.1.3.			Wall	2219-T87 AI	0.125"	οN				Plate deflected ~ 0.60", damage area 5.0" dia.
Odeg target angle Sheld #? 0.022 Yes 6 96,-31,56,05.071,1.05 Odeg target angle Shield #? 0.032 Yes Ske photo 6 72,124,133,15,174,166 0.375 Al-1100 Shield #1 0.025 Yes 0.47 × 0.427 7 219,175,206,195,152,197,20 0.45 graper angle Shield #1 0.027 Yes Max. 0.6160.44 7 219,175,206,195,152,197,20 0.45 graper angle Shield #2 0.037 Yes Max. 0.6160.44 7 219,175,206,195,152,197,20 0.45 Al-1100 Shield #2 0.66-176 Al 0.027 Yes 1.24gest 0.54 da 0.45 Al-1100 Shield #2 0.66-176 Al 0.037 Yes 0.44 v.0.47 0.45 Al-1100 Shield #1 666-176 Al 0.040 Yes 0.44 v.0.47 0.45 Al-1100 Shield #1 666-176 Al 0.040 Yes 0.44 v.0.47 0.45 Al-1100 Shield #2 666-176 Al 0.040 Yes 0.44 v.0.47 0.45 Al-1100 Shield #2 666-176 Al 0.040 Yes 0.44 v.0.47	1380	0.375" AI 1100	Shield #1		050'0	Yes	0.46" Dia.			Numerous holes, 3 large holes, 0.46"d, 0.19x0.49", 0.29x0.26"
Shield #3 Shield #3 Control Shield #3 Shield		0 deg. target angle	Shield #2		0.032"	Yes			.96,.37,.56,0.65,0.71,1.05	Numerous small holes, fine spray
Stuffing Yes Ske photo 0.375* Al-1100 Shield #2 0.0300 Yes 0.475* 0.427 7 2.19.175.20e.1.95,1.52.1.97.2 0.40g target angle Shield #2 0.0300 Yes Images 0.24* 0.44 7 2.19.175.20e.1.95,1.52.1.97.2 0.40g target angle Shield #2 6661-16.Al 0.0300 Yes Largest 0.84* dia 7 2.19.175.20e.1.95,1.52.1.97.2 0.375* Al-1100 Shield #2 6661-16.Al 0.000 Yes Largest 0.84* dia 6661-16.Al 0.000 Yes Largest 0.84* dia 0.000 0.000 Yes Largest 0.84* dia 0.000 0.000 Yes 1.000 0.0			Shield #3		0.032"	Yes			.72,1.24,1.33,1.5,1.74,1.66	
Wall 0125° Yes 36x.9, 180.01 0.375° Al-1100 Shield #1 0.020° Yes 0.47° x.042° 7 0.46g target angle Shield #1 6661-T6 AI 0.020° Yes 1.219.135.2.06.1.95,1.52.1.97.2 0.475° Al-1100 Shield #1 6661-T6 AI 0.020° Yes Largest 0.52° dia 0.475° Al-1100 Shield #1 6661-T6 AI 0.050° Yes Largest 0.52° dia 0.475° Al-1100 Shield #1 6661-T6 AI 0.0187° Yes 2.70° A.04° 0.475° Al-1100 Shield #1 2.219-T87 AI 0.187° Yes 0.47° x.0.4° 0.475° Al-1100 Shield #1 2.219-T87 AI 0.187° Yes 0.67° x.0.5° 0.475° Al-1100 Shield #1 6661-T6 AI 0.062° Yes 0.67° x.0.4° 0.475° Al-1100 Shield #2 6661-T6 AI 0.052° Yes 1.27° x.0.4° 0.46g target angle Wall 2.219-T87 AI 0.125° Yes 1.60° x.0.5° 0.475° Al-1100 Shield #2 6661-T6 A			Stuffing			Yes	See photo			
0.375' Al-1100 Shield #1 0.050' Yes 0.47" x 0.42" 7 219.1752.06.1951.52.197.20 0 deg target angle Shield #2 0.012" Yes Max. 061x0.44 7 219.1752.06.1951.52.197.20 0 deg target angle Shield #1 6661-16 Al 0.050" Yes Largest 0.32" dia 0.25* Al-1100 Shield #1 6661-16 Al 0.000" Yes 0.27" x 0.41" 0.25* Al-1100 Shield #1 6661-16 Al 0.000" Yes 0.47" x 0.44" 0.25* Al-1100 Shield #1 6661-16 Al 0.000" Yes 0.47" x 0.41" 0.04g target angle Shield #1 6661-16 Al 0.000" Yes 0.47" x 0.41" 0.04g target angle Shield #2 6661-16 Al 0.000" Yes 0.47" x 0.41" 0.04g target angle Shield #2 6661-16 Al 0.052" Yes 0.47" x 0.41" 0.04g target angle Shield #2 6661-16 Al 0.022" Yes 0.47" x 0.44" 0.04g target angle Shield #2 6661-16 Al 0.022"			Wall		0.125"	Yes	.36x.19,.15x0.17			10 craters with dimples, fine spray
Odeg target angle Shield #? Shield #? 0.022* Yes Amez, 061,054,152,1,97,20,61,951,152,1,97,20 0.375*Al·1100 Shield #? 6601-176 Al 0.050° Yes Largest 0.82° dia 7 2.19,175.2.06,1,95,1,521,97,20 0.045 target maple Shield #? 6601-176 Al 0.050° Yes Largest 0.84° dia 7 2.19,175.2.06,1,95,1,521,97,20 0.05 deg target maple Wall 2219-1787 Al 0.105° Yes 0.47° x 0.44° 6 6 6 1.76 Al 0.040° Yes 0.47° x 0.44° 6 6 6 6 1.76 Al 0.040° Yes 0.47° x 0.44° 6 6 6 6 1.76 Al 0.040° Yes 0.47° x 0.44° 0.05° 0.2° 0.4° <t< th=""><th>1381</th><th>0.375" AI-1100</th><th>Shield #1</th><th></th><th>0.050"</th><th>Yes</th><th>0.47" x 0.42"</th><th></th><th></th><th></th></t<>	1381	0.375" AI-1100	Shield #1		0.050"	Yes	0.47" x 0.42"			
0.375 Al-1100 Wall 6061-16 Al 0.125" Yes Max. 0610.044 0.dg target angle Shield #1 6061-16 Al 0.050° Yes Largest 0.8° dia 0.dg target angle Shield #1 6061-16 Al 0.050° Yes Largest 0.8° dia 0.dg target angle Wall 2219-178 Al 0.155° Yes 0.47° x.0.4° 0.dg target angle Wall 2219-178 Al 0.187° No 0.47° x.0.4° 0.dg target angle Wall 2219-178 Al 0.187° Yes 0.47° x.0.4° 0.dg target angle Wall 2219-178 Al 0.187° Yes 0.47° x.0.4° 0.dg target angle Shield #1 6061-176 Al 0.060° Yes 0.67° x.0.4° 0.dg target angle Shield #2 6061-176 Al 0.060° Yes 0.57° x.0.4° 0.dg target angle Shield #1 6061-176 Al 0.060° Yes 1.37° x.0.3° 0.dg target angle Shield #2 6061-176 Al 0.062° Yes 1.37° x.0.48° 0.dg target		0 deg target angle	Shield #2		0.032"	Yes			2.19,1.75,2.06,1.95,1.52,1.97,2.0	
0.3375" Al-1100 Shield #1 6661-16 Al 0.050" Yes Largest 0.82" dish 0.0 deg target angle Shield #2 6661-176 Al 0.050" Yes Largest 0.84" dish 0.0 deg target angle Shield #3 6061-176 Al 0.040" Yes 0.25".02.0.14" 0.0 deg target angle Wall 2219-1787 Al 0.187" Yes 0.47" x 0.44" 0.0 deg target angle Wall 2219-1787 Al 0.040" Yes 0.47" x 0.44" 0.0 deg target angle Shield #1 6061-176 Al 0.040" Yes 0.47" x 0.44" 0.0 deg target angle Shield #2 6061-176 Al 0.063" Yes 1.27" x 1.31" 0.0 deg target angle Shield #2 6061-176 Al 0.063" Yes 1.07" x 1.38" 0.0 deg target angle Shield #2 6061-176 Al 0.063" Yes 0.57" dia 0.0 deg target angle Shield #2 6061-176 Al 0.063" Yes 0.57" dia 0.0 deg target angle Shield #2 6061-176 Al 0.063" Yes 0.57"			Wali		0.125"	Yes	Max. 0.61x0.44			Numerous craters, large detached spall
Odeg target angle Shield #2 6061-16 Al 0.050° Yes Largest 0.84° dia Blanker MLI Blanket 20 layer Yes See photo Co.25° Al-1100 Shield #1 6061-16 Al 0.145° Yes 0.47° x 0.44° Co.25° Al-1100 Shield #1 6061-16 Al 0.145° Yes 0.47° x 0.44° Co.25° Al-1100 Shield #1 6061-16 Al 0.187° Yes 0.47° x 0.44° Co.25° Al-1100 Shield #1 6061-16 Al 0.187° Yes 0.47° x 0.47° Co.25° Al-1100 Shield #1 6061-16 Al 0.063° Yes Alaz 2.24x115° 7 8.5.107,68.68,47,42 Co.25° Al-1100 Shield #2 6061-16 Al 0.063° Yes Alaz 2.24x115° 7 8.5.107,68.68,47,42 Co.25° Al-1100 Shield #2 6061-16 Al 0.063° Yes 0.62° x 0.46° Co.25° Al-1100 Shield #2 6061-16 Al 0.063° Yes 0.62° x 0.46° Co.25° Al-1100 Shield #1 6061-16 Al 0.063° Yes 0.62° x 0.46° Co.25° Al-1100 Shield #1 6061-16 Al 0.063° Yes 0.62° x 0.46° Co.25° Al-1100 Shield #1 6061-16 Al 0.063° Yes 0.62° x 0.46° Co.25° Al-1100 Shield #1 6061-16 Al 0.063° Yes 0.65° x 0.46° Co.25° Al-1100 Shield #1 6061-16 Al 0.063° Yes 0.65° x 0.46° Co.25° Al-1100 Shield #1 6061-16 Al 0.063° Yes 0.65° x 0.46° Co.25° Al-1100 Shield #1 6061-16 Al 0.063° Yes 0.65° x 0.46° Co.25° Al-1100 Shield #1 6061-16 Al 0.063° Yes 0.65° x 0.46° Co.25° Al-1100 Shield #1 6061-16 Al 0.063° Yes 0.65° x 0.46° Co.25° Al-1100 Shield #1 6061-16 Al 0.063° Yes 0.65° x 0.46° Co.25° Al-1100 Shield #1 6061-16 Al 0.063° Yes 0.65° x 0.46° Co.25° Al-1100 Shield #1 6061-16 Al 0.063° Yes 0.65° x 0.46° Co.25° Al-1100 Shield #1 6061-16 Al 0.063° Yes 0.67° x 0.46° Co.25° Al-1100 Shield #1 6061-16 Al 0.063° Yes 0.67° x 0.46° Co.25° Al-1100 Shield #1 6061-16 Al 0.063° Yes 0.67° x 0.46° Co.25° Al-1100 Shield #1 6061-16 Al 0.063° Yes 0.67° x 0.46° Co.25° Al-1100 Shield #1 6061-16 Al 0.063° Yes 0.67° x 0.46° Co.25° Al-1100 Shield #1 6061-16	1383	0.375" Al-1100	Shield #1	6061-T6 Al	0.050"	Yes	Largest 0.52" dia			3 holes, largest hole measured
Biantet MLI Bianket 20 layer Yes See photo		0 deg target angle	Shield #2	6061-T6 Al	0.050"	Yes	Largest 0.84" dia	٦	3 11 11 11 11 11 11 11 11 11 11 11 11 11	Wagon wheel, largest hole measured
Wall 2219-T87 AI 0.125" Yes 0.27", 0.14" 0.05° AI-1100 Shield #1 6661-T6 AI 0.040° Yes 0.47" x 0.44° 0.025° AI-1100 Shield #1 6661-T6 AI 0.040° Yes 0.47" x 0.41° 0.025° AI-1100 Shield #1 6661-T6 AI 0.040° Yes 0.47" x 0.41° 0.055° AI-1100 Shield #2 6661-T6 AI 0.065° Yes 0.67" x 0.41° 0.055° AI-1100 Shield #2 6661-T6 AI 0.065° Yes 0.67" x 0.22 0.057° AI-1100 Shield #2 6661-T6 AI 0.065° Yes 0.67" x 1.31° 0.057° AI-1100 Shield #2 6661-T6 AI 0.065° Yes 0.57" dia 0.057° AI-1100 Shield #2 6661-T6 AI 0.063° Yes 0.57" dia 0.057° AI-1100 Shield #2 6661-T6 AI 0.053° Yes 0.65" dia 0.058° AI-1100 Shield #1 6201-T6 AI 0.053° Yes 0.65" dia 0.058° AI-1100 Shield #1 6061-T6 AI			Blanket	MLI Blanket	20 layer	Yes	See photo			
0.25" Al-1100 Shield #1 6061-T6 Al 0.040" Yes 0.47" x 0.44" 0.040g inget angle Wall 2219-T87 Al 0.187" Yes 0.47" x 0.41" 0.040g inget angle Wall 2219-T87 Al 0.187" Yes 1.47" x 0.41" 0.040g inget angle Shield #1 6061-T6 Al 0.063" Yes 0.62" x 0.56" 0.047g-Al-1100 Shield #1 6061-T6 Al 0.063" Yes 1.27" x 1.31" 0.047g-Al-1100 Shield #1 6061-T6 Al 0.063" Yes 1.60" x 1.38" 0.047g-Al-1100 Shield #1 6061-T6 Al 0.063" Yes 0.57" x 3.2" 0.04g target angle Shield #1 6061-T6 Al 0.032" Yes 0.52" x 0.48" 0.04g target angle Shield #1 6061-T6 Al 0.032" Yes 0.62" x 0.48" 0.04g target angle Shield #1 6061-T6 Al 0.032" Yes 0.62" x 0.48" 0.04g target angle Shield #2 6061-T6 Al 0.032" Yes 0.62" x 0.48" 0.0			Wali	2219-T87 AI	0.125"	Yes	0.25",0.2", 0.14"			3 holes, 9 craters with dimples, fine spray
0 deg target angle Wall 2219-T87 AI 0.187" No 0.2507A-110O Shield#I 6661-T6 AI 0.080" Yes 0.62"x 0.56" 0.4507A-110O Shield#I 6061-T6 AI 0.063" Yes 0.62"x 0.56" 0.4507A-110O Shield#I 6061-T6 AI 0.063" Yes 0.62"x 0.56" 0.4507A-110O Shield#I 6061-T6 AI 0.063" Yes 1.27"x 1.31" 0.450 target angle Shield#I 6061-T6 AI 0.063" Yes 1.60"x 1.38" 0.46g target angle Shield#I 6061-T6 AI 0.052" Yes 1.60"x 1.38" 0.45g target angle Shield#I 6061-T6 AI 0.032" Yes 0.65"x 6.48" 0.45g target angle Shield#I 6061-T6 AI 0.032" Yes 0.65"x 6.48" 0.45g target angle Shield#I 6061-T6 AI 0.050" Yes 3.20"x 3.0" 0.45g target angle Shield#I 6061-T6 AI 0.050" Yes 3.20"x 3.0" 0.45g target angle Shield#I <	1385	0.25" Al-1100	Shield #1	6061-T6 Al	0.040"	Yes	0.47" x 0.44"			
0.25Gr Al-1100 Shield #1 6661-T6 Al 0.040" Yes 0.47"x 0.41" 0.04g. target angle Shield #2 6661-T6 Al 0.087" Yes 0.62"x 0.56" 0.375" Al-1100 Shield #2 6661-T6 Al 0.063" Yes Max. 2.24x1.75" 7 85.1.07,68,68,47,42 0.64g target angle Shield #2 6661-T6 Al 0.063" Yes 1.27"x 1.31" 7 85.1.07,68,68,47,42 0.375" Al-1100 Shield #2 6661-T6 Al 0.063" Yes 0.57"dia 6.57"dia 0.45g target angle Shield #2 6661-T6 Al 0.032" Yes 0.57"x 3.42" 6.67"x 0.48" 0.45g target angle Shield #2 6661-T6 Al 0.032" Yes 0.63"x 0.48" 6.67"x 0.48" 0.375" Al-1100 Shield #1 6661-T6 Al 0.050" Yes 3.20"x 3.0" 6.67"x 0.84" 0.45g target angle Shield #2 6661-T6 Al 0.050" Yes 0.63"x 0.84" 6.67"x 0.84" 0.375" Al-1100 Shield #1 6661-T6 Al 0.050" Ye		0 deg. target angle	Wall	2219-T87 Al	0.187"	No				6 craters w/ dimples, wagon wheel, dam area 10"x11.5"
0 deg target angle Wall 2219-T87 AI 0.87" Yes Largest 67x.24" 0.375" AI-1100 Shield #1 6061-T6 AI 0.063" Yes 0.62x.0.56" 7 8.5.107,68.68.47,42 0 deg target angle Shield #2 6061-T6 AI 0.063" Yes 1.27" x1.31" 7 8.5.107,68.68.47,42 0 deg target angle Shield #2 6061-T6 AI 0.063" Yes Pin Hole 7 8.5.107,68.68.47,42 0 deg target angle Shield #2 6061-T6 AI 0.063" Yes 0.57" x0.48" 0.57" x0.48" 0 deg target angle Shield #2 6061-T6 AI 0.063" Yes 0.65" x0.48" 0.65" x0.48" 0 deg target angle Shield #2 6061-T6 AI 0.063" Yes 0.65" x0.48" 0.65" x0.48" 0 deg target angle Shield #2 6061-T6 AI 0.063" Yes 0.65" x0.48" 0.65" x0.48" 0 deg target angle Shield #2 6061-T6 AI 0.063" Yes 0.65" x0.48" 0.65" x0.48" 0 deg target angle Shield #2	1386	0.250" AI-1100	Shield #1	6061-T6 AI	0.040"	Yes	0.47" x 0.41"			
0.375" Al-1100 Shield #1 6061-T6 Al 0.063" Yes 0.62" x 0.56" A. S.107, 68, 68, 47, 42 0 deg target angle Shield #2 6061-T6 Al 0.063" Yes PLTX x 1.31" 7 8.5, 107, 68, 68, 47, 42 0.375" Al-1100 Shield #1 6061-T6 Al 0.063" Yes PTTX x 1.31" 8 8.5, 107, 68, 68, 47, 42 0.04g target angle Shield #2 6061-T6 Al 0.063" Yes 0.57" dia. 6 661-T6 Al 0.032" Yes 0.57" dia. 6 661-T6 Al 0.032" Yes 0.57" dia. 6 661-T6 Al 0.032" Yes 0.65" dia. 6 661-T6 Al 0.032" Yes 0.65" dia. 6 661-T6 Al 0.053" Yes 0.65" dia. 6 661-T6 Al 0.053" Yes 0.65" x 0.8" 6 661-T6 Al 0.050"		0 deg. target angle	Wall	2219-T87 Al	0.187"	Yes	Largest .67x.24"			4 holes, detached spalls, many craters, 6 craters w/ dimples
Odeg target angle Shield #2 6061-T6 AI 0.063" Yes N.2.24x1.75" 7 8.5.107,68.68.47,42 0.375" Al-1100 Shield #2 6061-T6 AI 0.063" Yes 1.27" x 1.31" 8.5.107,68.68.47,42 0.375" Al-1100 Shield #2 6061-T6 AI 0.063" Yes 0.57" dia 8.5.107,68.68.47,42 0.4 deg target angle Shield #2 6061-T6 AI 0.032" Yes 0.57" dia 8.5.107,68.68.47,42 0.375" Al-1100 Shield #2 6061-T6 AI 0.032" Yes 0.65" dia 9.65" dia <	1403	0.375" AI-1100	Shield #1	6061-T6 AI	0.063"	Yes	0.62" x 0.56"			Secondary holes 0.28 x 0.21", 0.17 x 0.2", & 0.11" dia
Shield #2 6061-T6 Al 0.063" Yes 1.27" x 1.31" 0.375" Al-1100 Shield #1 6061-T6 Al 0.053" Yes Pin Hole 0.375" Al-1100 Shield #1 6061-T6 Al 0.023" Yes 0.67" dia 0.375" Al-1100 Shield #2 6061-T6 Al 0.032" Yes 0.65" x 0.46" 0.375" Al-1100 Shield #1 6061-T6 Al 0.032" Yes 0.65" x 0.46" 0.375" Al-1100 Shield #1 6061-T6 Al 0.053" Yes 0.65" x 0.46" 0.375" Al-1100 Shield #1 6061-T6 Al 0.050" Yes 0.60" dia 0.375" Al-1100 Shield #1 6061-T6 Al 0.050" Yes 0.50" dia 0.375" Al-1100 Shield #1 6061-T6 Al 0.050" Yes 0.60" dia 0.375" Al-1100 Shield #2 6061-T6 Al 0.050" Yes 0.63" x 0.84" 0.375" Al-1100 Shield #1 6061-T6 Al 0.050" Yes 0.67" x 0.8" 0.375" Al-1100 Shield #1 6061-T6 Al		0 deg target angle	Shield #2	6061-T6 AI	0.063"	Yes	Max. 2.24x1.75"	7	.8,.5,1.07,.68,.68,.47,.42	Damage area 3.25" x 2.75"
0.375" Al-1100 Wall 2219-T87 Al 0.125" Yes Pin Hole 0.045 target angle Shield #1 6061-T6 Al 0.063" Yes 0.65" dia. 0.04 target angle Shield #2 6061-T6 Al 0.032" Yes 0.65" dia. 0.375" Al-1100 Shield #1 6061-T6 Al 0.063" Yes 0.65" x 0.48" 0.375" Al-1100 Shield #1 6061-T6 Al 0.063" Yes 0.65" x 0.48" 0.45 target angle Shield #1 6061-T6 Al 0.053" Yes 0.50" x 3.0" 0.45 target angle Shield #2 6061-T6 Al 0.050" Yes 0.60" dia. 0.45 deg target angle Shield #1 6061-T6 Al 0.050" Yes 0.67" x 0.8" 45 deg target angle Shield #1 6061-T6 Al 0.050" Yes 0.14" x 0.28" 0.375" Al-1100 Shield #1 6061-T6 Al 0.050" Yes 0.15" dia. 45 deg target angle Shield #2 6061-T6 Al 0.050" Yes 0.15" x 0.8" 0.375" Al-1100 Shield #2 6061-T6 Al 0.050" Yes 0.			Shield #2	IA 9T-1909	0.063"	Yes	1.27" x 1.31"		:	~25 craters w/ dimp., fine spray, dam area 5" x 5.5"
0.375" Al-1100 Shield #1 6061-T6 Al 0.063" Yes 0.57" dia. 0 deg target angle Shield #2 6061-T6 Al 0.032" Yes 1.60" x 1.38" 0 deg target angle Shield #1 6061-T6 Al 0.032" Yes 0.63" x 0.48" 0.375" Al-1100 Shield #1 6061-T6 Al 0.063" Yes 0.63" x 0.48" 0 deg target angle Shield #2 6061-T6 Al 0.063" Yes 0.60" dia. 0 deg target angle Shield #2 6061-T6 Al 0.050" Yes 0.60" dia. 0 deg target angle Shield #2 6061-T6 Al 0.050" Yes 0.60" dia. 0 deg target angle Shield #2 6061-T6 Al 0.050" Yes 0.60" dia. 0 375" Al-1100 Shield #2 6061-T6 Al 0.050" Yes 0.60" dia. 0 375" Al-1100 Shield #2 6061-T6 Al 0.053" Yes 0.14" x 0.28" 45 deg target angle Shield #2 6061-T6 Al 0.053" Yes 0.15" x 1.25" 0 375" Al-			Wall	2219-T87 Al	0.125"	Yes	Pin Hole			2 cracks .32 and 0.11" long, dimp, fine spray dam area 2.75x3
O deg target angle Shield #2 6661-T6 Al 0.032" Yes 1.60" x 1.38" O deg target angle Shield #2 6661-T6 Al 0.032" Yes 0.62" x 0.48" 0.375" Al-1100 Shield #1 6061-T6 Al 0.0125" Yes 0.60" x 3.0" 0 deg target angle Shield #2 6061-T6 Al 0.053" Yes 0.60" x 3.0" 0 deg target angle Shield #2 6061-T6 Al 0.050" Yes 0.60" x 3.42" 0 deg target angle Shield #2 6061-T6 Al 0.050" Yes 0.60" x 3.42" 0 deg target angle Shield #2 6061-T6 Al 0.050" Yes 0.60" x 3.42" 45 deg target angle Shield #1 6061-T6 Al 0.050" Yes 0.63" x 3.42" 0.375" Al-1100 Shield #1 6061-T6 Al 0.050" Yes 0.63" x 0.8" 0.375" Al-1100 Shield #1 6061-T6 Al 0.050" Yes 0.17" x 0.95" 0.375" Al-1100 Shield #2 6061-T6 Al 0.063" Yes 0.15" x 0.95"	1404	0.375" Al-1100	Shield #1	6061-T6 Al	0.063"	Yes	0.57" dia.			Secondary holes 0.19" x 0.15", 0.13" x 0.11", 0.21" x 0.14"
Shield #2 6661-T6 Al 0.032" Yes 3.53" x 3.42" 0.375" Al-1100 Shield #1 6661-T6 Al 0.053" Yes 0.62" x 0.48" 0.375" Al-1100 Shield #1 6661-T6 Al 0.063" Yes 3.20" x 3.0" 0.375" Al-1100 Shield #1 6661-T6 Al 0.050" Yes 3.20" x 3.42" 0.375" Al-1100 Shield #1 6061-T6 Al 0.050" Yes 3.20" x 3.42" 0.375" Al-1100 Shield #1 6061-T6 Al 0.050" Yes 3.20" x 3.42" 0.375" Al-1100 Shield #1 6061-T6 Al 0.050" Yes 0.63" x 0.84" 45 deg target angle Shield #1 6061-T6 Al 0.050" Yes 0.63" x 0.84" 45 deg target angle Shield #1 6061-T6 Al 0.050" Yes 0.14" x 0.28" 45 deg target angle Shield #1 6061-T6 Al 0.053" Yes 0.15" al 0.375" Al-1100 Shield #2 6061-T6 Al 0.050" Yes 0.15" x 1.25" 0.45 deg target angle Shiel		0 deg target angle	Shield #2	6061-T6 Al	0.032"	Yes	1.60" x 1.38"			Numerous craters w/ dimp., wagon wheel, dam area 4.25x6.75"
Wall 2219-T87 Al 0.125" Yes 0.62" x 0.48" 0.375" Al-1100 Shield #1 6061-T6 Al 0.063" Yes 0.63" dia 0 deg target angle Shield #2 6061-T6 Al 0.063" Yes 0.60" dia 0.375" Al-1100 Shield #1 6061-T6 Al 0.050" Yes 0.60" dia 0.375" Al-1100 Shield #1 6061-T6 Al 0.050" Yes 0.60" dia 0.375" Al-1100 Shield #2 6061-T6 Al 0.050" Yes 0.60" dia 0.375" Al-1100 Shield #1 6061-T6 Al 0.050" Yes 0.63" x 0.84" 45 deg target angle Shield #1 6061-T6 Al 0.050" Yes 0.63" x 0.84" 0.375" Al-1100 Shield #1 6061-T6 Al 0.050" Yes 0.15" dia 0.375" Al-1100 Shield #1 6061-T6 Al 0.063" Yes 0.15" dia 0.375" Al-1100 Shield #2 6061-T6 Al 0.060" Yes 0.15" dia 0.375" Al-1100 Shield #2 6061-T6 Al			Shield #2	6061-T6 Al	0.032"	Yes	3.53" x 3.42"			Damage area 4.75" x 4.25"
0.375" Al-1100 Shield #1 6061-T6 Al 0.063" Yes 0.63" dia 0 deg target angle Shield #2 6061-T6 Al 0.063" Yes 3.20" x 3.0" 0 deg target angle Shield #1 6061-T6 Al 0.050" Yes 0.60" dia 0 deg target angle Shield #1 6061-T6 Al 0.050" Yes 0.60" x 3.42" 0 deg target angle Shield #1 6061-T6 Al 0.050" Yes 0.60" x 3.42" 0 375" Al-1100 Shield #2 6061-T6 Al 0.050" Yes 0.63" x 0.84" 45 deg target angle Shield #2 6061-T6 Al 0.050" Yes 0.63" x 0.84" 0 375" Al-1100 Shield #2 6061-T6 Al 0.050" Yes 0.14" x 0.28" 0 375" Al-1100 Shield #2 6061-T6 Al 0.063" Yes 0.15" dia 0 375" Al-1100 Shield #2 6061-T6 Al 0.063" Yes 0.15" dia 0 375" Al-1100 Shield #2 6061-T6 Al 0.063" Yes 0.15" dia 0 deg target angle <th></th> <th></th> <th>Wall</th> <th>2219-T87 AI</th> <th>0.125"</th> <th>Yes</th> <th>0.62" x 0.48"</th> <th></th> <th></th> <th>4 petals, petal lengths 1.34,0.73,1.19,1.0, dam area 3.5" dia</th>			Wall	2219-T87 AI	0.125"	Yes	0.62" x 0.48"			4 petals, petal lengths 1.34,0.73,1.19,1.0, dam area 3.5" dia
0 deg target angle Shield #2 6661-T6 Al 0.063" Yes 3.20" x 3.0" 0.375" Al-1100 Shield #1 6061-T6 Al 0.050" Yes 0.60" dia. 0.375" Al-1100 Shield #2 6061-T6 Al 0.050" Yes 0.63" x 0.84" 45 deg target angle Shield #2 6061-T6 Al 0.050" Yes 0.63" x 0.84" 45 deg target angle Shield #2 6061-T6 Al 0.050" Yes 0.63" x 0.84" 45 deg target angle Shield #2 6061-T6 Al 0.050" Yes 0.03" x 0.8" 45 deg target angle Shield #1 6061-T6 Al 0.050" Yes 0.14" x 0.28" 45 deg target angle Shield #1 6061-T6 Al 0.063" Yes 0.15" dia. 0.375" Al-1100 Shield #1 6061-T6 Al 0.063" Yes 0.15" dia. 0.375" Al-1100 Shield #1 6061-T6 Al 0.063" Yes 0.15" dia. 0.375" Al-1100 Shield #1 6061-T6 Al 0.060" Yes 0.15" dia. 0 deg tar	1405	0.375" Al-1100	Shield #1	6061-T6 Al	0.063"	Yes	0.63" dia			
Wall 2219-T87 Al 0.125" No 0.375" Al-1100 Shield #1 6061-T6 Al 0.050" Yes 0.60" dia. 0.4 deg target angle Shield #2 6061-T6 Al 0.050" Yes 3.20" x 3.42" 45 deg target angle Shield #1 6061-T6 Al 0.050" Yes 0.63" x 0.84" 45 deg target angle Shield #2 6061-T6 Al 0.050" Yes 0.14" x 0.28" 45 deg target angle Shield #1 6061-T6 Al 0.053" Yes 0.14" x 0.28" 45 deg target angle Shield #1 6061-T6 Al 0.063" Yes 0.79" x 1.25" 45 deg target angle Shield #1 6061-T6 Al 0.063" Yes 0.15" dia. 0 375" Al-1100 Shield #1 6061-T6 Al 0.063" Yes 0.15" dia. 0 0.375" Al-1100 Shield #1 6061-T6 Al 0.063" Yes 1.0" dia. 0 0.375" Al-1100 Shield #2 6061-T6 Al 0.080" Yes 1.0" dia. 0 0.375" Al-1100 Shield #3 2.219-T87		0 deg target angle	Shield #2	6061-T6 AI	0.063"	Yes	3.20" x 3.0"			Numerous holes, craters, dimples, and det. spalls, wagon wheel
0.375" Al-1100 Shield #1 6061-T6 Al 0.050" Yes 0.60" dia. 0 deg target angle Shield #2 6061-T6 Al 0.050" Yes 3.20" x 3.42" 0.375" Al-1100 Shield #1 6061-T6 Al 0.050" Yes 0.63" x 0.84" 45 deg target angle Shield #2 6061-T6 Al 0.050" Yes 0.61" x 0.28" 0.375" Al-1100 Shield #1 6061-T6 Al 0.050" Yes 0.14" x 0.28" 45 deg target angle Shield #2 6061-T6 Al 0.063" Yes 0.15" dia. 0.375" Al-1100 Shield #2 6061-T6 Al 0.063" Yes 0.15" dia. 0.375" Al-1100 Shield #1 6061-T6 Al 0.063" Yes 0.15" dia. 0.375" Al-1100 Shield #1 6061-T6 Al 0.080" Yes 1.2" x 1.12" 0 deg target angle Shield #2 6061-T6 Al 0.050" Yes 1.2" x 1.12" 0 deg target angle Shield #3 2024 Al 0.020" Yes 2.43" x 1.95" 0 deg target ang			Wall	2219-T87 Al	0.125"	ž				Fine spray, plate deflection ~0.20", damage area ~9.5" dia.
0 deg target angle Shield #2 6061-T6 Al 0.050" Yes 3.20" x 3.42" 0.375" Al-1100 Shield #1 6061-T6 Al 0.050" Yes 0.63" x 0.84" 45 deg target angle Shield #2 6061-T6 Al 0.050" Yes 0.04" x 0.28" 0.375" Al-1100 Shield #1 6061-T6 Al 0.050" Yes 0.14" x 0.28" 45 deg target angle Shield #2 6061-T6 Al 0.063" Yes 0.79" x 1.25" 45 deg target angle Shield #2 6061-T6 Al 0.063" Yes 0.15" dia. 0.375" Al-1100 Shield #2 6061-T6 Al 0.063" Yes 0.15" dia. 0.375" Al-1100 Shield #2 6061-T6 Al 0.080" Yes 1.0" dia. 0.375" Al-1100 Shield #2 6061-T6 Al 0.050" Yes 1.22" x 1.12" 0 deg target angle Shield #3 2024 Al 0.020" Yes 1.85" x 1.60" 0 deg target angle Shield #3 2024 Al 0.020" Yes 2.43" x 1.95"	1406	0.375" AI-1100	Shield #1	6061-T6 AI	0.050"	Yes	0.60" dia.			Secondary hole 0.18" dia.
Wall 2219-T87 Al 0.125" No 45 deg target angle Shield #1 6061-T6 Al 0.050" Yes 0.63" x 0.84" 45 deg target angle Shield #2 6061-T6 Al 0.050" Yes Largest 1.2 x 0.8" 0.375" Al-1100 Shield #1 6061-T6 Al 0.053" Yes 0.14" x 0.28" 45 deg target angle Shield #2 6061-T6 Al 0.063" Yes 0.79" x 1.25" 0.375" Al-1100 Shield #2 6061-T6 Al 0.063" Yes 0.15" dia. 0.375" Al-1100 Shield #1 6061-T6 Al 0.080" Yes 1.0" dia. 0.375" Al-1100 Shield #2 6061-T6 Al 0.080" Yes 1.0" dia. 0 deg target angle Shield #2 6061-T6 Al 0.050" Yes 1.22" x 1.12" 0 deg target angle Shield #3 2024 Al 0.020" Yes 2.43" x 1.95" 0 deg target angle Wall 2219-T87 Al 0.125" Yes 2.33" x 1.75"		0 deg target angle	Shield #2	6061-T6 Al	0.050"	Yes	3.20" x 3.42"			Numerous holes, craters, dimples, and detached spalls, ~3 petal
0.375" Al-1100 Shield #1 6061-T6 Al 0.050" Yes 0.63" x 0.84" 45 deg target angle Shield #2 6061-T6 Al 0.050" Yes Largest 1.2 x 0.8" 0.375" Al-1100 Shield #1 6061-T6 Al 0.063" Yes 0.14" x 0.28" 45 deg target angle Shield #2 6061-T6 Al 0.063" Yes 0.07" x 0.95" 0.375" Al-1100 Shield #2 6061-T6 Al 0.063" Yes 0.15" dia. 0.375" Al-1100 Shield #1 6061-T6 Al 0.080" Yes 1.0" dia. 0 deg target angle Shield #2 6061-T6 Al 0.080" Yes 1.2" x 1.12" 0 deg target angle Shield #2 6061-T6 Al 0.050" Yes 1.25" x 1.15" 0 deg target angle Shield #3 2024 Al 0.050" Yes 2.43" x 1.95" 0 deg target angle Wilness #1 2024 Al 0.050" Yes 2.33" x 1.75"			Wall	2219-T87 AI	0.125"	ν̈́				Fine spray, plate deflection ~0.37", damage area 9.5 x 10"
45 deg target angle Shield #2 6061-T6 Al 0.050" Yes Largest 1.2 x 0.8" 0.375" Al-1100 Shield #1 6061-T6 Al 0.063" Yes 0.14" x 0.28" 45 deg target angle Shield #2 6061-T6 Al 0.063" Yes 0.67" x 0.95" 0.375" Al-1100 Shield #2 6061-T6 Al 0.063" Yes 0.15" dia. 0.375" Al-1100 Shield #1 6061-T6 Al 0.080" Yes 1.0" dia. 0 deg target angle Shield #2 6061-T6 Al 0.080" Yes 1.2" x 1.12" 0 deg target angle Shield #3 2024 Al 0.050" Yes 1.85" x 1.60" Wall 2219-T87 Al 0.125" Yes 2.43" x 1.95"	1407	0.375" Al-1100	Shield #1	6061-T6 Al	0.050"	Yes	0.63" x 0.84"			
Wall 2219-T87 Al 0.125" Yes 0.14" x 0.28" 0.375" Al-1100 Shield #1 6061-T6 Al 0.063" Yes 0.67" x 0.95" 45 deg target angle Shield #2 6061-T6 Al 0.063" Yes 0.79" x 1.25" 0.375" Al-1100 Shield #1 6061-T6 Al 0.080" Yes 1.0" dia 0 deg target angle Shield #2 6061-T6 Al 0.080" Yes 1.22" x 1.12" 0 deg target angle Shield #3 2024 Al 0.050" Yes 1.85" x 1.66" Wall 2219-T87 Al 0.125" Yes 2.43" x 1.95"		45 deg target angle	Shield #2	6061-T6 AI	0.050"	Yes	Largest 1.2 x 0.8"			Numerous holes, craters, dimples, and detached spalls
0.375" Al-1100 Shield #1 6061-T6 Al 0.063" Yes 0.67" x 0.95" 45 deg target angle Shield #2 6061-T6 Al 0.063" Yes 0.79" x 1.25" 0.375" Al-1100 Shield #1 6061-T6 Al 0.080" Yes 1.0" dia 0 deg target angle Shield #2 6061-T6 Al 0.050" Yes 1.22" x 1.12" 0 deg target angle Shield #3 2024 Al 0.020" Yes 1.85" x 1.66" Wall 2219-T87 Al 0.125" Yes 2.43" x 1.95" Witness #1 2024 Al 0.020" Yes 2.33" x 1.75"			Wall	2219-T87 AI	0.125"	Yes	0.14" x 0.28"			2 holes .13 x .11", ~25 dimples, fine spray, dam area 9 x 12"
45 deg target angle Shield #2 6061-T6 Al 0.063" Yes 0.79" x 1.25" 0.375" Al-1100 Shield #1 6061-T6 Al 0.080" Yes 1.0" dia. 0 deg target angle Shield #2 6061-T6 Al 0.050" Yes 1.22" x 1.12" Shield #3 2024 Al 0.020" Yes 1.85" x 1.60" Wall 2219-T87 Al 0.125" Yes 2.43" x 1.95" Witness #1 2024 Al 0.020" Yes 2.33" x 1.75"	1408	0.375" AI-1100	Shield #1	6061-T6 AI	0.063"	Yes	0.67" x 0.95"			
Wall 2219-T87 Al 0.125" Yes 0.15" dia. 0.375" Al-1100 Shield #1 6061-T6 Al 0.080" Yes 1.0" dia. 0 deg target angle Shield #2 6061-T6 Al 0.050" Yes 1.22" x 1.12" Shield #3 2024 Al 0.020" Yes 1.85" x 1.60" Wall 2219-T87 Al 0.125" Yes 2.43" x 1.95" Witness #1 2024 Al 0.020" Yes 2.33" x 1.75"		45 deg target angle	Shield #2	6061-T6 Al	0.063"	Yes	0.79" x 1.25"			Holes, craters, and dimples throughout panel, detached spall
0.375" Al-1100 Shield #1 6061-T6 Al 0.080" Yes 1.0" dia. 0 deg target angle Shield #2 6061-T6 Al 0.050" Yes 1.22" x 1.12" Shield #3 2024 Al 0.020" Yes 1.85" x 1.60" Wall 2219-T87 Al 0.125" Yes 2.43" x 1.95" Witness #1 2024 Al 0.020" Yes 2.33" x 1.75"			Wall	2219-T87 AI	0.125"	Yes	0.15" dia.			~ 25 dimples, fine spray
Shield #2 6061-T6 Al 0.050" Yes 1.22" x 1.12" Shield #3 2024 Al 0.020" Yes 1.85" x 1.60" Wall 2219-T87 Al 0.125" Yes 2.43"x 1.95" Witness #1 2024 Al 0.020" Yes 2.33" x 1.75"	1410	0.375" AI-1100	Shield #1	6061-T6 AI	.080'0	Yes	1.0" dia.			Edge of hole bent ~0.21" inward (toward projectile entrance)
Shield #3 2024 Al 0.020" Yes 1.85" x 1.60" Wall 2219-T87 Al 0.125" Yes 2.43"x 1.95" Witness #1 2024 Al 0.020" Yes 2.33" x 1.75"		0 deg target angle	Shield #2	6061-T6 AI	0.050"	Yes	1.22" x 1.12"			Edge of hole bent ~0.23" outward (away from proj. entrance)
2219-T87 Al 0.125" Yes 2.43"x 1.95" sss #1 2024 Al 0.020" Yes 2.33" x 1.75"			Shield #3	2024 AI	0.020"	Yes	1.85" x 1.60"			Plate has curled petals around the hole, 16 petals
sss #1 2024 AI 0.020" Yes 2.33" x 1.75"			Wall	2219-T87 Al	0.125"	Yes	2.43"x 1.95"			5 cracks on rear, fine spray, dam. area 8.75" x 9.5"
			Witness #1	2024 A1	0.020"	Yes	2.33" x 1.75"			Damage area 4.25" x 4.50"

						T			
Shot	2nd Projectile	Description	Material	I hickness	Pen.	Hole Diameter	reta	Petal Length of Crack Petals	Damage Description
		witness #2	2024 AI	0.020	3 ;	1.90 A 1.02	1		Daniage area 3.0 A 2.3
		Witness #3	2024 AI	0.020	Yes	1.85" x 0.78"	1		Damage area 1.75 x 1.0
1411	0.375" AI-1100	Shield #1	6061-T6 Al	0.050"	ζes	0.89" dia.	1		Edge of hole bent outward ~ 0.11"
	0 deg target angle	Shield #2	6061-T6 Al	0.063"	Yes	0.95 & .18 x .14"			Edge of holes bent outward ~ 0.15"
		Wall	2219-T87 Al	0.125"	Yes	Max 3.11" x 2.5"			~ 30 dimples, fine spray
		Witness #1	2024 AI	0.020"	Yes		7 1	1.6,1.18,1.38,1.18,.76,1.14,0.75"	
		Witness #2	2024 Al	0.020"	Yes		5		Damage area 5.0" dia.
		Witness #3	2024 AI	0.020"	Yes		5		Damage area 4.5" x 3.75"
1412	0.187" Al-1100	Shield #1	6061-T6 Al	0.032"	Yes	0.38" x 0.33"			
	0 deg. target angle	Shield #2	6061-T6 Al	0.032"	Yes		4 (0.92",1.19",1.47",1.0"	Many small holes, slight wagon wheel, dam area 8.75 x 8.5"
		Wall	6061-T6 Al	0.063"	No				Dim. on rear, fine spray, slight defl. of plate, dam area 4.5" dia
1413	0.375" Al-1100	Shield #1	6061-T6 Al	0.050"	Yes	Largest 1.01x1.18			Other holes .52x.45", 0.43x0.34", small petals formed on rear
	45 deg target angle	Shield #2	6061-T6 AI	0.063"	Yes	Largest 1.59x1.76			Other holes .39x.5", .41x.3", Irg hole has 7 petals, craters/ dim.
		Wall	2219-T87 AI	0.125"	Yes	Largest .93x.51"			8 holes total, craters w/ dim., fine spray, dam area 9.25x8.5"
1414	0.375" AI-1100	Shield #1	6061-T6 AI	.080.0	Yes	0.75" x 0.96"			
	45 deg target angle	Shield #2	6061-T6 Al	0.032"	Yes	Largest 1.04x.83"			Numerous holes radiate outward, dam area 12" x 9.5"
		Shield #3	6061-T6 Al	0.063"	Yes		8	1.79,1.67,.72,.45,.78,.94,1.18,.3	1.79,1.67,.72,.45,.78,.94,1.18,.3fFine spray, damage area 7.0" x 9.25"
		Wall	6061-T6 Al	0.063"	No	0.07" x 0.03"			Plate deflected ~0.25", dam area 4"x4.5", crack on rear 0.165"
1415	0.187" Al-1100	Shield #1	6061-T6 Al	0.032"	Yes	Largest .33x.43"			Other holes 0.24x0.18", 0.17x0.12", 0.13x0.08"
	45 deg target angle	Shield #2	6061-T6 Al	0.032"	Yes	Largest .36x.33"			Numerous holes, craters & dimples, fine spray, dam area 9.5x9"
		Wali	6061-T6 Al	0.063"	Yes	Largest .14x.25"			Numerous holes, -30 dimples, fine spray, dam. area 6.5x9.0"
1419	0.375" AI-1100	Shield #1	6061-T6 AI	0.063"	Yes	0.97" x 0.68"			Second hole 0.51" x 0.33"
	45 deg target angle	Shield #2	6061-T6 AI	0.050"	Yes	0.89" x 0.40"			Holes, craters & dimples radiating throughout plate, det. spalls
		Wali	6061-T6 Al	0.125"	Yes	0.15" x 0.17"			~ 30 craters with dimples, fine spray
1420	0.375" Al-1100	Shield #1	6061-T6 Al	.080.0	Yes	0.71,0.16",0.11"	0		
	0 deg target angle	Shield #2	6061-T6 AI	0.032"	Yes		8	1.23, 0.16, 0.87, 0.40, 0.57, 0.86, 1.04, 1.59	14,1.59
		Shield #3	6061-T6 Al	0.063"	Yes		7	1.65,1.54,2.16,2.23,2.5,2.41,2.46	
		Wall	6061-T6 AI	0.063"	No		0		Plate bent away from projectile impact, dam area 4.5"x5.68"
1425	0.375" Al-1100	Shield #1	6061-T6 AI	.080.0	Yes	0.77" x 0.71"	0		Smaller hole meas. 2,17,12,16,07", craters, detached spall
	0 deg. target angle	Shield #2	6061-T6 AI	0.032"	Yes		8	0.9,0.89,0.43,0.68,0.56,0.62,0.52,0.88	3,0.88
		Stuffing	Kevlar/ MLI	10 layers	Yes	See photo			
		Wall	2219-T87 Al	0.125"	ν°				Slight deflection of plate, fine spray, dam. area 4.6 x 4.25"
1426	0.375" AI-1100	Shield #2	6061-T6 Al	0.063"	Yes	0.76" x 1.1"			Numerous holes, craters and detached spalls
	45 deg target angle	Wall	2219-T86 AI	0.125"	Yes				2 small pin holes, numerous craters
1427	0.375" AI-1100	Shield #1	6061-T6 Al	0.050"	Yes	.69.0 x .68.0	7		10 small holes, numerous craters
	45 deg target angle	Shield #2	6061-T6 Al	0.063"	Yes		<u>></u>	0.74, 27, 39, 45, 24, 25, 16, 48, 53	33
		Wall	2219-T86 Al	0.125"	Yes	0.07 x 0.08"			Several craters, dam area 5.18" dia.
1429	0.375" AI-1100	Shield #1	6061-T6 Al	.080.0	Yes	0.75" x 0.95"			Small hole 0.02" dia.
	45 deg target angle	Stuffing	Kevlar	6 layers	Yes		9	1.08,1.25,1.37,1.27,1.76,1.67	
		Shield #2	6061-T6 Al	0.063"					
		Wall	6061-T6 AI	0.063"	No				~ 16 craters w/ dimples, slight defl. of plate, dam area 3.5 x3.8"
1430	0.375" Al-1100	Shield #1		.080.0	Yes	0.74" x 0.91"			Fine spray
	45 deg. target angle	Stuffing	Kevlar	8 layers	Yes		7	3.18,3.94,3.75,3.72,2.77,5.11,5.16	9
		Shield #2		0.032"	Yes	See photo	1		
		Wall	6061-T6 Al	.080"	Yes	0.05"			Numerous craters w/ dimples, fine spray, dam area 4" x 5.45"

			Metalial	Thinkney	Do.	Uolo Diomotor	Data 1	Datal I anoth of Crack Datale	Description
300t 1431	0.375" AI-1100	Shield #1	6061-T6 Al	0.080"	Yes	1			Fine spray on front and rear of panel
	45 deg. target angle	Shield #2	6061-T6 Al	0.032"	Yes	┢	2	66, 58, 4, 61, 64, 57, 74, 48, 27, 42	.42
		Stuffing	Kevlar/MLI	10 layers		See photo			
		Wall	2219-T86 AI	0.125"	No		П		8 craters w/ dimples, fine spray, dam area 3.55x5.07"
1432	0.375" Al-1100	Shield #1	9T-1909	0.032"	Yes				4 largest holes 0.52", 0.34x 0.29", 0.33x 0.26", 0.14"
	0 deg. target angle						7		
1433	0.375" AI-1100	Shield #1	6061-T6	0.050"	Yes	Largest 0.89 x 0.63	_		Smaller holes 0.51x0.38", 0.17x0.11", numerous craters/spalls
	45 deg. target angle	Shield #2	6061-T6	0.032"	Yes		7	1.12,.57,.47,.43,.5,.54,.85	
		Stuffing	Kevlar	8 layers	Yes	See photo	7		
		Shield #3	6061-T6	0.032"	Yes		∞	3.54,2.89,2.66,2.44,3.57,3.72,2.24,3.42	24,3.42
		Wali	6061-T6	.080.0	No		П		12 craters w/ dimples, ~ 0.19" defl., dam area 3.75 x 4.5"
1436	0.187" AI-1100	Shield #1	6061-T6	0.012"	Yes	0.33x0.32,0.28x0.23"			
	0 deg. target angle	Shield #2	6061-T6	0.040"	Yes	0.85" x 1.05"	2 (0.17,0.52,0.14	Fine spray, 2 holes, 2nd hole 0.05" dia.
		Wall	91-1909	0.040"	Yes		5 (0.59,0.52,0.41,0.38,0.37	Det. spall, many craters with dimples, fine spray, 3 pin holes
1437	0.187" AI-1100	Shield #1	91·1909	0.012"	Yes	0.32" x 0.25"			Numerous pin holes
	0 deg. target angle	Stuffing	MLI Blanket		Yes	See photo			
		Shield #2	6061-T6	0.040"	Yes		9	0.57,0.94,1.18,1.22,0.5,0.4	
		Wall	6061-T6	0.040"	Yes	Largest .12x.09"			Numerous small holes and craters
1438	0.187" AI-1100	Shield #1	6061-T6	0.012"	Yes	Largest .325 x .27"			
	0 deg. target angle	Stuffing	MLI Blanket		Yes	See photo			
		Shield #2	91-1909	0.040"	Yes		7	1.46,0.36,1.23,1,.85,0.71	
		Wall	91-1909	0.040"					Missing
1439	0.187" Al-1100	Shield #1	91-1909	0.012"	Yes	0.35" x 0.31"			Numerous pin holes
		Stuffing	MLI Blanket		Yes	See photo			
		Shield #2	9T-1909	0.040"	Yes		<u>~</u>	.90,.73,.23,.75,.75,.78,.9,.99	
		Wall	6061-T6	0.040"	Yes	0.125" dia.			3 meas holes .125",.1 x .06", .063x.074", pin holes, fine spray
1442	0.187" AI-1100	Shield #1		0.012"	Yes	0.31" x 0.22"			Several pin holes around projectile entrance
1443	0.187" AI-1100	Shield #1		0.012"	Yes	0.31" dia.			Small hole below and to the right 0.04", numerous pin holes
1444	0.187" Al-1100	Shield #1	6061-T6 Al	0.012"	Yes	0.295" dia.	Г		Shield severely bent, shield cracked on bottom right side
1446	0.187" Al-1100	Shield #1	6061-T6 AI	0.012"	Yes	0.270" dia.			Shield severely bent, numerous pin holes
1450	0.5" Al-1100	Shield #1	6061-T6 Al	0.050"	Yes	0.720" dia.			Detached spall
	0 deg target angle	Shield #2	6061-T6 AI	0.050"	Yes	4.43" max dia.			Wagon wheel,many craters, & dimples
		Wall	2219-T87 AI	0.125"	Yes	0.811" x 0.708"	4	4.34",5.19",4.29",3.25"	Numerous craters
1451	0.5" Al-1100	Shield #1	6061-T6 Al	0.050"	Yes	1.163" x 0.794"	0		Elliptical hole
	45 deg target angle	Al Mesh			Yes	See photo	0		
		Nextel 62		6 layers	Yes	See photo	0		
		Kevlar 710		6 layers	Yes	See photo	0		
		MLI Blanket			Yes	See photo	0		
		Wall	2219-T87 Al	0.125"	Yes	0.661"	3	2.80",1.93",2.16"	Numerous craters, no dimples
1452	0.5" AI-1100	Shield #1	6061 T6 Al	0.063"	Yes	1.168" x 1.040"	0		Several debris holes and craters
	45 deg target angle	Al Mesh			Yes	See photo	0		
		Nextel 62		6 layers	Yes	See photo	0		
		Kevlar 710		6 layers	Yes	See photo	0		

Shot	2nd Projectile	Description	Material	Thickness	Pen.	Hole Diameter	Petal Length of Crack Petals	Damage Description
		MLI Blanket		6 layers	Yes	See photo	0	
		Wall	2219-T87 Al	0.125"	Yes	0.25"	3 0.81",2.12",1.41"	Elliptical damage area 6.042"x4.670"
1453	0.5" AI-1100	Shield	6061 T6 Al	0.063"	Yes	1.114" x 0.825"	0	Debris holes, 2 attached spalls, 4 dimples
	45 deg target angle	Al Mesh				See photo	0	
		Nextel 62		6 layers		See photo	0	
		Kevlar 710		6 layers		See photo	0	
		MLI Blanket		6 layers		See photo	0	
		Wall	2219-T87 AI	0.190"	οN		0	6 lg. craters, ~ deflection of wall 0.821"
1454	0.5" Al-1100	Shield #1	6061 T6 Al	0.063"	Yes	1.101" x 0.835"	0	Debris holes and craters, 2 detached spalls
	45 deg target angle	Al Mesh				See photo	0	
		Nextel 62		6 layers		See photo	0	
		Kevlar 710		6 layers		See photo	0	
		MLI Blanket		6 layers		See photo	0	
		Wall	2219-T87 AI	0.190"	No		0	4 lg. craters, many pits, dam. area 6.1 "x4.64", wall defl. ~.362"
1455	0.5" AI-1100	Shield #1	6061 T6 Al	0.063"	Yes	0.773" max. dia.	0	1 debris hole
	0 deg target angle	B2+ Stuffing			Yes	See photo	0	
		MLI			Yes	See photo	0	
		Wall	2219-T87 AI	0.190"	Yes	0.880"	5 3.43,1.53,3.15, 2.05,0.73	Damage area 7.176"
		Witness #1			Yes	3.214"	0	Maximum length from edge to edge
		Witness #2			Yes	3.407"	0	Maximum length from edge to edge
		Witness #3			Yes	3.318"	0	Maximum length from edge to edge
1456	0.5" Al-1100	Shield #1	6061 T6 AI	0.063"	Yes	1.143"x 0.840"	0	Plated bent toward projectile
	45 deg target angle	Kevlar		26 layers	Yes	See photo	0	
		MLI			Yes	See photo	0	
		Wall	2219-T87 AI	0.190"	Yes	0.727"x 0.365"	0	Many pits, no dimples
1457	Bad Shot						0	
1458	0.5" Al-1100	Shield #1	6061 T6 Al	0.063"	Yes	1.126"x 0.836"	0	
	45 deg target angle	AF26 Nextel		3 layers	Yes	See photo	0	
		Kevlar 120		11 layers	Yes	See photo	0	
		MLI			Yes	See photo	0	
		Wall	2219-T87 AI	0.190"	Yes	0.035"	0	Fine spray, damage area 5.684"x 3.343
1459	Bad Shot						0	
1466	0.313" AI-1100	Shield #1	6061 T6 Al	0.032"	Yes	0.750"x 0.522"	0	Fine spray
	45 deg target angle	Nextel		3 layers	Yes	See photo	0	
		Kevlar		3 layers	Yes	See photo	0	
		MLI		10 layers	Yes	See photo	0	
		Wall	2219-T87 AI	0.100"	Yes	0.836"x 0.264"	4 1.71",1.74",1.96",1.34"	Length of petal crack
		Witness #1			ŝ		0	Numerous large craters
		Witness #2			ŝ		0	No apparent damage
						Ī		

Shot	2nd Projectile	Description	Material	Thickness	Pen.	Hole Diameter	Petal	Petal Length of Crack Petals	Damage Description
1467	0.375" AI-1100	Shield #1		0.040"	Yes	Г	0		Shield bent outward
	45 deg target angle	Al Mesh			Yes	See photo	0		
		Nextel		2 layers	Yes	See photo	0		
		Kevlar		7 layers	Yes	See photo	0		
		MLI		15 layers	Yes	See photo	0		
		Wall		0.125"	Yes	0.552"x 0.294"	4	1.82",1.92",1.59",2.08"	Length of petal crack
		Witness #1			No		0		Lg. plate defl., 1 detached spall, craters
1468	Bad Shot						0		
1469	0.5" Al-1100	Shield #1	2024 AI	0.025"	Yes		0		
	75 deg target angle	Nextel		2 layers	Yes	See photo	0		
		Kevlar		1 layers	Yes	See photo	0		
		MLI		11 layers	Yes	See photo	0		
		Wall	6061-T6	0.063"	Yes	1.716"	S	2.07,1.55,0.91,1.52,2.17	Length of petal crack
	· i	Witness #1			Yes		0		Damage area 3.05" dia.
		Witness #2			Yes	.188,.16,.52x.26	0		3 holes & 3 craters
1470	0.5" Al-1100	Shield #1	6061-T6 AI	0.063"	Yes	0.81" x 1.10"			
	45 deg target angle	Stuffing			Yes	See photo			
		Wall	2219-T87 AI	0.190"	No				2 dimples on rear, 10 craters w/o dimp., dam area 4.25×4.5 "
1476	0.313" AI-1100	Shield #1	6061-T6 AI	0.040"	Yes	0.54 x 0.79"			
	45 deg target angle	Nextel		2 layers	Yes	See photo			
		Kevlar		7 layers	Yes	See photo			
		MLI		15 layers	Yes	See photo			
		Wall	2219-T87 Al	0.125"	No				Crack 0.07" long, fine spray, 2 dimples, dam area 2.0×2.75 "
		Witness #1	2024 AI	0.020"	No				Attached spall, damage area 0.23" x 0.18"
1477	0.375" Al-1100	Shield #1	6061-T6 Al	0.040"	Yes	0.59" x 0.82"			
	45 deg target angle	Nextel		4 layers	Yes	See photo			
		Kevlar		4 layers	Yes	See photo			
		MLI		15 layers	Yes	See photo			
		Wall	2219-T87 AI	0.125"	Yes	0.84" x 0.85"	4	1.03,1.57,0.65,1.84"	Damage area 2.875" x 4.0"
		Witness #1	2024 AI	0.020"	Yes				5 pin holes, damage area 2.5" x 3.0"
		Witness #2	2024 AI	0.020"	No				5 craters w/ dimples
1478	0.375" Al-1100	Shield #1	6061-T6 Al	0.040"	Yes	0.80" x 0.58"			9 secondary, plate bent toward proj entrance, dimp on front
	45 deg target angle	Shield #2	6061-T6 Al	0.080"	Yes	2.20" x 1.14"			Numerous craters w/ dimples, dam area 4.5 x 4.375"
		Wall	2219-T87 AI	0.125"	Yes	1.23" x 1.19"			2 smaller holes 0.17 x 0.14" & 0.14" d. dam area 2.88 x 3.38"
		Witness #1	2024 AI	0.020"	Yes	4.45" x 3.16"			8 petals
		Witness #2	2024 AI	0.020"	Yes	3.72" x 2.27"			8 petals
1481	0.313" AI-1100	Shield #1	6061-T6 AI	0.063"	Yes	0.68" x 0.97"			6 secondary holes
	45 deg target angle	Shield #2	6061-T6 AI	0.032"	Yes	2.94" x 3.52"	∞	1.18, 1.25, 0.28, 1.1, 1.19, 0.58, 0.47, 0.62	, 0.47, 0.62
		MLI		12 layers	Yes	See photo			
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1			Material	Thiobase	Dan	Hole Diameter D	Detail I enoth of Crack Details	Damage Description
Shot	zna Projecnie	Description	Marchai 2010 TOT A1	I IIICAIICSS	2 2	Т	rengin of clack I class	Dimulse cratere fine enray dam area 3 0" v 4 75"
1		wali	7719-18/ AI	0.100	ŝ	2.00 iong		Diniples, cracis, tine spray, call area 3.0 A 4.73
		Witness #1	2024 AI	0.020"	Yes	Pin hole		Attached spalls, damage area 1.875" x 2.375"
1482	0.313" AI-1100	Shield #1	6061-T6 Al	0.063"	Yes	0.67" x 0.84"		2 small secondary holes, fine spray
	45 deg target angle	Nextel		1 layer	Yes	See photo		
		Kevlar		3 layers	Yes	See photo		
		MLI		12 layers	Yes	See photo		
		Wall	2219-T87 AI	0.100	Yes	Max. 0.6 x 0.48"	5 1.21,1.19,1.63,1.18,1.77"	Damage area 4.0" x 6.0"
		Witness #1	2024 AI	0.020"	No			4 dimples on rear, damage area 3.375" x 4.5"
1483	0.375" Al-1100	Shield #1	6061-T6 Al	.080.0	i			
	45 deg target angle	Shield #2	6061-T6 AI	0.040"	Yes	2.64" x 2.75"		Slight petal effect, petals have holes, craters, & dimples
		Blanket	MLI	15 layers	Yes	See photo		
		Wall	2219-T87 AI	0.125"	Yes	0.98" x 1.59"		1 petal, crack lengths 1.25 & 1.72, fine spray, dam area 5 x 7"
		Witness #1	2024 AI	0.020"	Yes	0.80" x 0.59"		~8 craters w/ dimples dam. area 2.0" x 1.75"
		Witness #2	2024 AI	0.020"	Yes	2.65" x 3.83"		Damage area 4.25" x 5.75"
		Witness #3	2024 AI	0.020"	Yes	Pin holes		9 pin holes , attached spalls, dam area 3.5" x 4.0"
1484	0.375" Al-1100	Shield #1	6061-T6 Al	0.080"	Yes	0.76" x 1.0"		
	45 deg target angle	Nextel		2 layer	Yes	See photo		
		Kevlar		2 layers	Yes	See photo		
		MLI		15 layers	Yes	See photo		
		Wall	2219-T87 AI	0.125"	Yes	0.94" x 1.40"		3 petals, crack length 0.49, .73, .58,1.8", dam area 4.25 x 4.75
		Witness #1	2024 AI	0.020"	Yes	Crack 1.51" long		Crack 1.51 x 0.27", 5 pin holes, dam area 4.0" x 4.5"
		Witness #2	2024 AI	0.020"	οN			Dent in plate 0.50" long
1485	0.250" Al-1100	Shield #1	6061-T6 Al	0.050"	?			
	0 deg target angle	Wall	2219-T87 Al	0.125"	i			
		Witness #1	2024 AI	0.020"	No			Attached spalls, ~11 dimples, dam area 1.875" x 1.375"
1489	0.250" Al-1100	Shield #1	6061-T6 Al	0.0075"	i			
	0 deg target angle	Wall	2219-T87 AI	0.125"	i			
		Witness #1	2024 AI	0.020"	Yes	0.29" x 0.26"		Numerous craters w/ dimples, damage area 3.25" x 2.875"
		Witness #2	2024 AI	0.020"	οN			Small dent 0.25" long, attached spall, dam area 0.38" x 0.50"
1491	0.250" Al-1100	Blanket	Kevlar	l ply	Yes	See photo		
	0 deg target angle	Blanket	B ₄ C		Yes	See photo		
		Blanket	ΥF	0.20"	Yes	See photo		
		Blanket	Kevlar	5 layers	Yes	See photo		
		Wall	2219-T87 AI	0.125"	i			
1493	0.250" Al-1100	Shield #1	2024 AI	0.025"	Yes	0.37" x 0.56"		0.08" x 0.11" secondary holes, and 2 pin holes
	45 deg target angle	Blanket	Mesh		Yes	See photo		
		Blanket	Nextel	2 layers	Yes	See photo		
		Blanket	Kevlar	4 layers	Yes	See photo		
		Blanket	MLI	9 layers	Yes	See photo		

Shot	2nd Projectile	Description	Material	Thickness	Pen	Hole Diameter	Petal	Petal Length of Crack Petals	Damage Description
		Wall	6061-T6	0.080"	Yes	T	5	1.07,0.86,1.07,0.43,1.17"	Damage area (max dim) 2.25" x 2.25"
		Witness #1	2024 AI	0.020"	Yes	2 pin holes			Damage area 3.25" diameter
1494	0.375" AI-1100	Shield #1	6061-T6 AL	0.040"	Yes	0.60" x 0.88"			
	45 deg target angle	Blanket	Mesh		Yes	See photo			
		Blanket	Nextel	4 layers	Yes	See photo			
		Blanket	Kevlar	4 layers	Yes	See photo			
		Blanket	MLI	15 layers	Yes	See photo			
		Wall	2219-T87 AI	0.125"	Yes	Max. 0.7" x 0.4"	4 (0.88", 0.31", 0.96", 0.75"	Damage area 3.625" x 4.5"
		Witness #1	2024 AI	0.020"	Yes	Lrg 0.32" x .29"			3 holes, damage area 3.75 x 4.0"
		Witness #2	2024 AI	.020.0	οÑ				2 craters w/ dimples, damage area 0.41" x 0.14"
1495	0.375" AI-1100	Shield #1	2024 AI	0.040"	Yes	0.53" x 0.76"			9 secondary holes
	45 deg target angle	Blanket	Mesh		Yes	See photo			
		Blanket	Nextel	2 layers	Yes	See photo			
		Blanket	Kevlar	4 layers	Yes	See photo			
		Blanket	MLI	9 layers	Yes	See photo			
		Wall	6061-T6 Al	.080.0	Yes	Max 1.58 x 1.41"	5	0.38,0.47,0.2,0.42,0.15	2 small holes, craters dimples, fine spray, dam area 5.75 x 8.5"
		Witness #1	2024 AI	0.020"	Yes	Max. 2.71 x 2.3"			Attached spall around hole, damage area 3.375" x 3.5"
1496	0.313" Al-1100	Shield #1	2024 AI	0.040"	Yes	0.46" x 0.51"			
	25 deg target angle	Blanket	Al Mesh		j				
		Blanket	Nextel	2 layers	i				
		Blanket	Kevlar	4 layers	i				
		Blanket	MLI	9 layers	į				
		Wall	6061-T6 AI	080:0	Yes	Max 3.25 x 3.48"	8	2,1.72,1.33,1.7,1.83,1.94,1.59,1.84	.84
		Witness #1	2024 AI	0.020"	Yes	Max 4.44 x 4.6"	8		Damage area 4.75 x 5.75"
		Witness #2	2024 AI	0.020"	Yes	Max 2.5" x 0.52"			Attached spalls, damage area 4.75 x 5.5"
1498	0.250" AI-1100	Shield #1	6061-T6 Al	0.050"	Yes	0.58" x 0.60"			
1502	0.5" Al-1100	Shield #1	6061-T6 Al	0.063"	Yes	1.150"x 0.837"	0		Severely bent outward , craters , detached spail
	45 deg target angle	MLI		20 layers	Yes	See photo	0		
		Nextel		3 layers	Yes	See photo	0		
		Keviar		6 layers	Yes	See photo	0		
		Graphite Ep.		Sheet	Yes	See photo	0		
		Wall	2219-T87 AI	0.188"	Yes	0.137"	4	0.59",0.52",0.88",0.34"	Fine spray, dam. area 4.69" x 6.0"
1503	0.5" Al-1100	Shield #1	6061 T6 Al	0.063"	Yes	1.118" x 0.822"	0		
	45 deg target angle	MLI			Yes	See photo	0		
		AF-62 Nextel		5 layers	Yes	See photo	0		
		Graphite Ep.		Sheet	Yes	See photo	0		
		Wall	2219-T87 Al	0.188"	Yes	0.362" x 0.223"	0		Fine spray
		Witness #1			Yes	0.61"x.46" & 0.39" x 0.19"	0.19"		Damage area 1.43"x 1.67"

ial Thickness Pen. Hole Diameter Petal Length of Crack Petals Damage Description		ial Thickness Pen. Hole Diameter Petal Length of Crack Petals Damage Description	Yes 0.327" 0	Yes 0.40" 0 Minor detached spalls	Yes 0.42" 0 Fine spray	Yes 0.45"x 0.35" 0 Damage area 1.1" x 1.3"	Yes 0.351" 0	Yes 0.413" x 0.387" 0 Fine spray	Yes 0.470" x 0.575" 0 Fine spray	L
						_		\vdash	<u> </u>	V.c. 0400" × 0.480"
		Thickness	Y	λ	Y	Y	X	X	λ.	
on Material		on Material								
tile Description	Projectile	tile Description	S.S. Shield #1	Wall #1	Wall #2	Wall #3	S.S. Shield #1	Wall #1	Wall #2	C# 11 - 123
ot 2nd Projectile	304 Stainless Steel Projectile	ot 2nd Projectile	0.25" 304 S.S.				0.25" 304 S.S.			
Shot	304	Shot	1505				1506			

Alum	Aluminum Projectile						Ì		
Shot	2nd Projectile	Description	Material	Thickness	Pen.	Hole Diameter	Petal	Petal Length of Crack Petals	Damage Description
1507	0.25" AI-1100	Shield #1	2219 T87 Al	0.125"	Yes	0.685"	0		
		Shield #2	6061-T6 Al	0.032"	Yes		8	Max=1.62", Min=1.23	Numerous small holes, fine spray
		Shield #3	2024 AI	0.020"	Yes		7	Max=2.2", Min=1.68"	
		Shield #4	2024 AI	0.020"	Yes		5	2.96",2.25",1.7",2.28",3"	
		Wall	6061-T6 Al	0.080"	No		0		Slight indentation at impact
1509	0.313" Al-1100	Shield #1	6061-T6 Al	0.040"	Yes	0.722" x 0.527"	0		Fine spray
	45 deg target angle	MLI					0		
		Nextel		2 layers			0		
		Kevlar		2 layers	-		0		
		Wall	2219 T87 AI	0.125"	No		0		Craters, damage area 5.17" x 3.15"
1524	0.25" AI-1100	Shield #1	2219 T87 AI	0.125"	Yes	.69.0	0		
		Shield #2	6061-T6 Al	0.032"	Yes		10	Max.=2.13",Min=1.5"	Numerous small holes
		Shield #3	6061-T6 AI	0.012"	Yes		10	Max=1.88",Min=0.743"	Numerous craters, small holes
		Shield #4	6061-T6 AI	0.012"	Yes		7	Max=2.43", Min=1.67"	
		Wall	6061-T6 Al	.080.0	No		0		Slight indent, fine spray, dam area 2.19" dia
1528	0.313" Al-1100	Shield #1	6061-T6 Al	0.040"	Yes	0.72" x 0.52"	0		
	45 deg target angle	MLI		15 layers	Yes	See photo	0		
 		Nextel		2 layers	Yes	See photo	0		
		Kevlar		2 layers	Yes	See photo	0		
		Wall	2219 T87 AI	0.125"	Yes	0.53"	1	0.38", 0.47"	Damage area 2.5"
		Witness #1			Yes	0.03"	0		21 craters
1529	0.187" AI-110	Shield #1	2219 T87 AI	0.125"	Yes	879	0		
	0 deg target angle	Shield #2	6061-T6 AI	0.032"	Yes		9	.92",1.13",1.17",1.18",.82",1.13"	
		MLI		25 layers			0		
		Shield #3	6061-T6 Al	0.012"	Yes	Max .16,Min .02	0		8 holes total, damage area 2.25" dia.

Shot	2nd Projectile	Description	Material	Thickness	Pen.	Hole Diameter	Petal	Petal Length of Crack Petals	Damage Description
		MLI		15 layers			0		
		Shield #4	6061-T6 Al	0.012"	٥N		0		2 craters
		Wall	6061-T6 AI	.080'0	No		0		No visible damage
1531	0.313" AI-1100	Shield #1	6061-T6 AI	0.050"	Yes	0.61" Dia			Numerous small holes
	0 deg target angle	Wall	2219 T87 Al	0.125"	Yes				
		Witness #1	2024 AI	0.020"	Yes	2.75"x 1.0"			
		Witness #2	2024 AI	0.020"	Yes		3	.2,.25",.18"&.34,.38,.35"	3 holes, 2 w/ 3 petals & 1 w/ debris in hole, 3rd small
		Witness #3	2024 AI	0.020"	No				1 large crater 0.22" x 0.15"
1545	0.375" Al-1100	Shield #1	6061-T6 Al	0.050"	Yes	0.65"x 0.91"			Plate bulged toward proj, several small holes & craters
	45 deg target angle	MLI		15 layers	Yes	See photo			
		Nextel		4 layers	Yes	See photo			
		Kevlar		4 layers	Yes	See photo			
		Wall	2219 T87 AI	0.125"	Yes	0.50"x 0.066"			1 large horizontal crack 2.9", several large craters
		Witness #1	2024 AI	0.020"	οN				Damage area 1.22"x 0.64", 3 dimples on rear
1546	0.375" Al-1100	Shield #1	6061-T6 Al	0.032"	Yes	.61x1.05,.28x.41"			Shield severely bulged toward the projectile entrance
	60 deg target angle	MLI		10 layers	Yes	See photo			
		Nextel		3 layers	Yes	See photo			
		Kevlar		3 layers	Yes	See photo			The second secon
		Wall	2219 T87 Al	0.093"	Yes				Vert. crack 1.4", wall bulged toward proj,many craters, no hole
		Witness #1	2024 AI	0.020"	No				No apparent damage
1548	0.375" AI-1100	Shield #1	6061-T6 Al	0.050"	Yes	0.65"x 0.89"			Shield bulged toward proj. entrance
	60 deg target angle	Shield #2	2219 T87 AI	.960'0	Yes	Max. 2.54x1.47"			Large hole w/ fingers, craters, 3 cracks .37,.18,.29, small hole
		Wall	2219 T87 AI	0.125"	Yes		4	2.13",1.72",1.67",1.73"	2 holes, small hole 0.16" to left of lg hole
		Witness #1	2024 AI	0.020"	Yes	0.6"x0.63"x0.64"			Numerous small holes, largest hole triangular shaped
		Witness #2	2024 AI	0.020"	Yes		3	0.16",0.38",0.55"	4 holes, 1 crack joins 2 holes

CONCLUSIONS

A number of physical parameters from high velocity impacts on space station walls and bumpers were measured and recorded. The amount of impact damage observed includes a large range of combinations.

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